The Role Of Summer Leads In Melting Sea Ice

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LONG-TERM GOALS

The long-term goal of this study is to determine the processes which control the input of heat into summer leads and the disposition of this heat into lateral melting, bottom melting and heat storage.

OBJECTIVES

The objectives of this study are to:

- Determine the albedo of lead surfaces as a function of solar altitude, surface roughness (wind speed and fetch), and clouds (transmittance).
- Determine optical properties of leads and their effect on the absorption and penetration of solar radiation.
- Determine salt and temperature stratification within leads and their dependence on melt rate, air-sea heat exchanges and turbulent mixing forced by the wind and ice-ocean velocity difference.
- Balance the heat and freshwater budgets of leads and assess the effects of atmospheric, ice, and oceanic forcing on the components of the balances.

APPROACH

We participated in the Surface Heat Budget of the Arctic (SHEBA) field experiment in the Beaufort Sea. Measurements were made from lead edges and from a small (3-m) boat. Measurements included: 1) incoming and outgoing solar radiation over leads; 2) vertical profiles of temperature, salinity and optical properties on vertical sections across and around the perimeter of leads; and 3) velocity from drogued drifters. Observations of temperature and conductivity (from which salinity was calculated) were made in the same lead, named Nanook, from 7 June to 8 August, 1998. This lead was located near the SHEBA ice camp which drifted from 77.0N, 166.7W to 78.6N, 158.7W during this period. Observations were made for several hours nearly every day with Seabird conductivity-temperature-depth (CTD) instruments deployed from a small boat. Two instruments were used, one mounted on the bow which measured temperature and conductivity at a depth of about 15 cm while the boat was underway, and the second

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which profiled to a depth of several meters while slowly towed by the boat. The perimeter of the lead was mapped by the use of two GPS units, one on the boat and the second on an adjacent ice floe. On 11 July

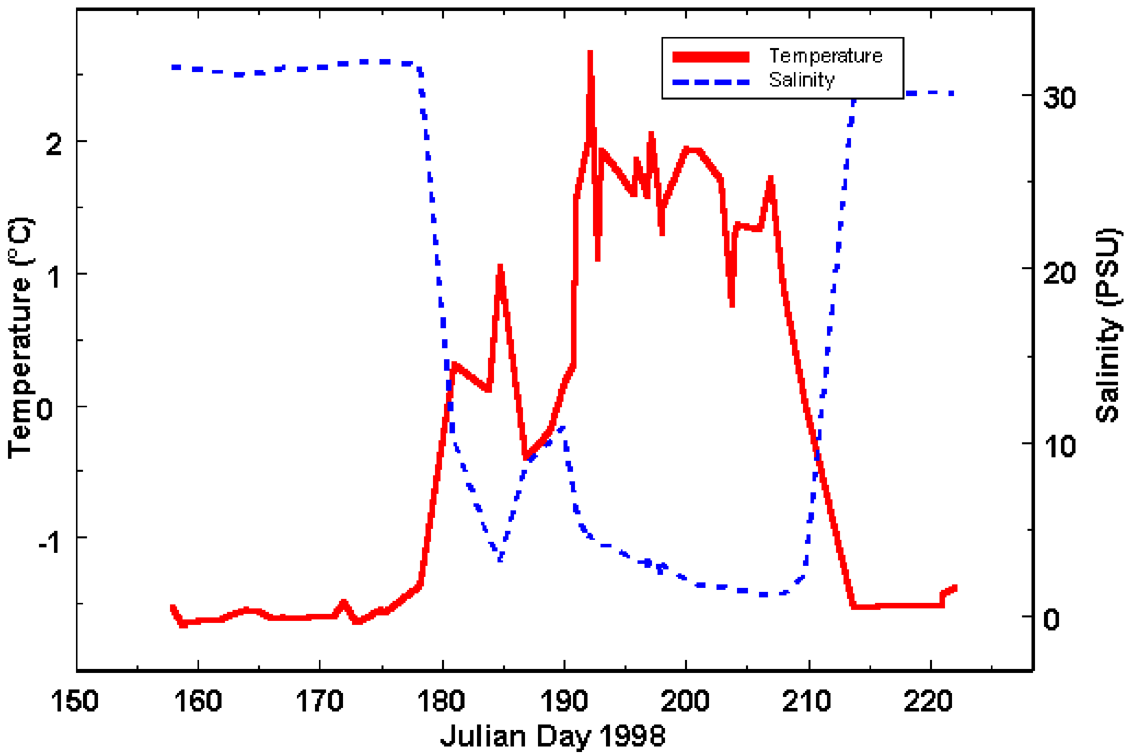

Figure 1. Median temperature and salinity at a depth of 15 cm in Nanook lead plotted vs. time.

The observations were made underway from a small boat with a CTD mounted on the bow. The observations illustrate the establishment of a warm, fresh surface layer at the beginning of the melt season which persisted for a month until it is mixed by a storm near the end of July the area of Nanook lead was 12,000 m^2, the length of its perimeter was 700 m and the maximum distance across the lead was 200 m. The length of the perimeter was underestimated because small-scale irregularities in the boundary were not resolved by the navigation.

In addition to the measurements made in Nanook lead, profiles of temperature and conductivity were measured in other leads on several occasions by use of an instrument lowered from a hovering helicopter.

WORK COMPLETED

A preliminary analysis of the data has been completed and data files have been submitted to SHEBA archives. We participated in a data analysis workshop and have contributed to an article in EOS by

Perovich et al. (1999). A paper on preliminary results was presented at the annual meeting of the American Meteorological Society (Pegau and Paulson, 1999).

RESULTS

At the beginning of the summer season, temperature and salinity in Nanook lead were nearly uniform within an upper mixed layer approximately 30 m in depth with temperature close to the freezing point. This mixed layer formed during the previous winter under the influence of wind-forced ice motion, surface cooling, and brine rejection associated with ice formation. As solar insolation increased during the summer, the total surface heat flux into leads and ice floes changed from net cooling to net heating, thereby melting ice and snow. The meltwater formed a salt-stratified surface layer in the lead with temperature above freezing. The near-surface temperature of Nanook lead was consistently above freezing after 21 June. By 11 July the average temperature of Nanook lead at a depth of 15 cm ranged from 0.9 to 2.2 C with a mean of 1.6 C and the thickness of the warm, fresh, surface layer was approximately 0.5 m and surface salinity was about 4 psu. As summer progressed, the modified layer deepened to 1.3 m and salinity decreased to a uniform 2 psu in the upper 0.9 m. The median temperature and salinity at a depth of 15 cm in Nanook lead is shown in Figure 1 as a function of time.

On 28 July, winds at the SHEBA ship increased to 10 ms and remained near this level during most of the following day. The wind stress caused ice motion and turbulent mixing which was sufficiently energetic to deepen the surface mixed layer in Nanook lead to 15 m as observed on 1 August. A sequence of temperature and salinity profiles beginning before the storm is shown in Figure 2 together with ice speed. Following the onset of the storm, the thickness of the stratified layer decreased rapidly to the thickness of the surrounding ice floes. After 1 August, the melt rate was not sufficient to reestablish a persistent, low-salinity layer at the surface.

The summer cycle observed in Nanook lead illustrates the establishment of a fresh, warm, surface layer with very low surface salinity (2 psu) and temperature well above freezing (2 C). The strong vertical stratification associated with this layer inhibited mixing until near the end of July when a passing storm generated enough ice motion and turbulence to vertically mix the 1-m thick surface layer down to a depth of 15 m. The stratified surface layer limited the vertical transfer of heat to melt bottom ice, especially in the first part of the summer when the depth of the surface layer was less than the draft of surrounding ice floes. Hence the role of stratified surface layers in leads may be to apportion more heat to melting the sides of ice floes than to their bottoms.

IMPACT/APPLICATIONS

The persistent vertical density stratification observed in summertime Arctic leads is larger than anywhere in the world ocean. Analysis of our observations will lead to an improved understanding of the processes which determine the establishment and evolution of a warm, fresh, surface layer in Arctic leads and the role of this layer in controlling the flow of heat used to melt the sides and bottoms of ice floes. This improved understanding will aid in the development and improvement of coupled models of air-ice-ocean interaction.

TRANSITIONS

We have submitted our data to the SHEBA archive and it is available for use by other SHEBA investigators.

RELATED PROJECTS

None.

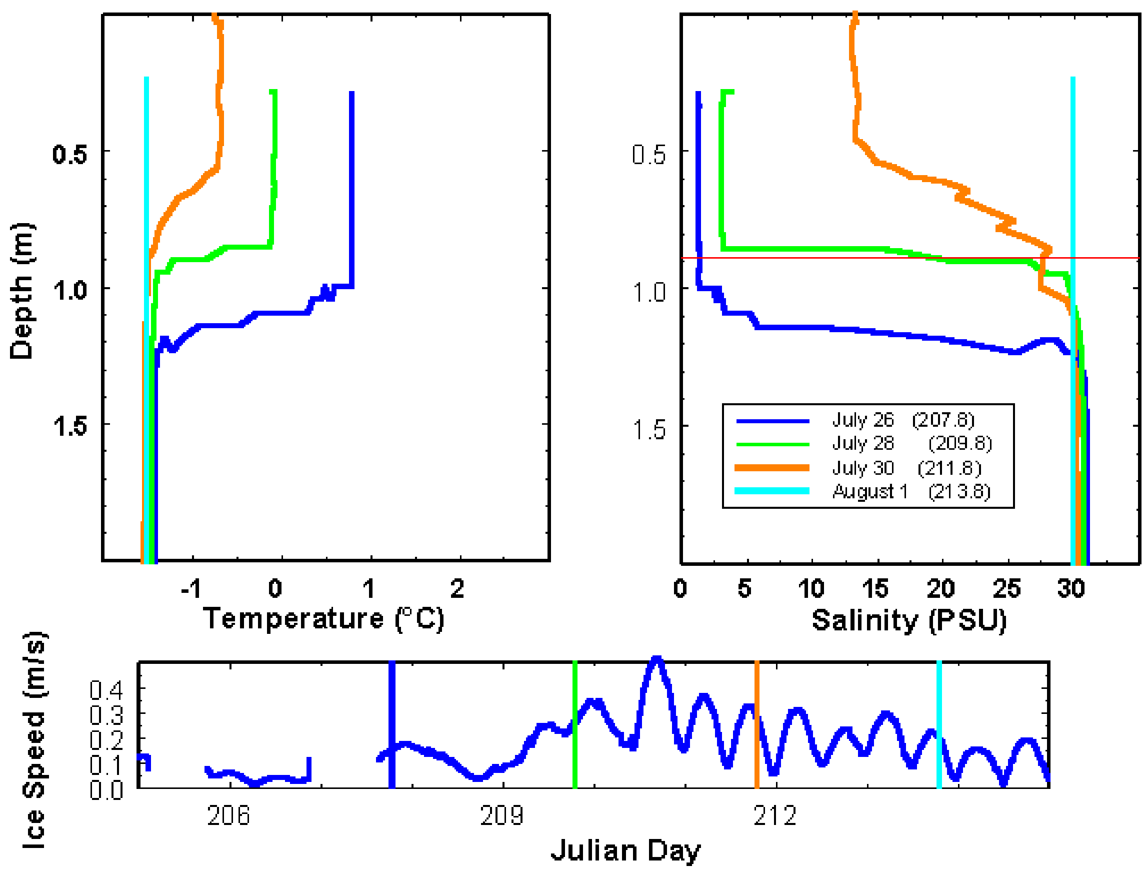

Figure 2. Temperature and salinity profiles in Nanook lead which illustrate the mixing of a fresh, warm, surface layer due to the action of a storm (winds in excess of 10 m/s) in late July. The horizontal line across the right panel shows the depth of surrounding ice floes. The lowest panel (courtesy of M. McPhee) shows ice speed with a maximum of 0.5 m/s associated with the storm. The vertical lines in this panel are at the times of the profiles.

PUBLICATIONS

Pegau, W. S. and C. A. Paulson, 1999: The role of summer leads in the heat and mass balance of the upper Arctic Ocean. Preprint volume, Fifth Conference on Polar Meteorology and Oceanography, 10-15 Jan, 1999, American Meteorological Society, 401-403.

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